DETAILED DESCRIPTION OF THE DRAWINGS

[0042] By way of introduction, **figure 1** schematically illustrates in a block diagram 100 the organization and setup of a semiconductor chip production installation, for which a method according to the invention can be used for the monitoring of a manufacturing process of a plurality of wafers.

[0043] The overall manufacturing process, referred to in figure 1 by a first block 101, is grouped by way of example into four production areas 102, 103, 104, 105,

- a first area, into which the front-end processes of the chip production are grouped (block 102),
- a second area of the manufacturing process, into which the back-end processes are grouped (block 103),
- a third area of the manufacturing process, which relates to the support, that is to say the backup, of the individual manufacturing processes (block 104),
- a fourth area, which relates to the process technology and the process integration (block 105).

[0044] In the case of the front-end processes 102, the following process technologies and the devices set up for carrying out the corresponding processes are provided in particular:

- a furnace for heating up the respective wafer to be processed,
- a device for carrying out Rapid Thermal Processing (RTP),
- a device for etching the wafer, for example for wet-etching or for dry-etching,
- a device for cleaning, for example washing, the wafer,
- a device for carrying out various lithographic steps,
- a device for chemical-mechanical polishing (CMP),
- a device for carrying out an ion-implantation in predetermined areas of the wafer or of the chip respectively to be produced,
- devices for applying materials to the wafer, for example devices for

depositing materials from the vapor phase, that is for example devices for carrying out Physical Vapor Deposition (PVD) or Chemical Vapor Deposition (CDV), or a device for epitaxially growing material on a substrate,
- metrology devices, i.e. measuring devices,
- devices for carrying out tests on the respective wafers.

[0045] The back-end processes relate in particular to the following areas:

- the assembly of the chips in packages,
- the final test of the finished and packaged chip,
- the introduction of information, for example product information, into or onto the package of the respective chip, and also
- generally the technologies used in the back-end area for packaged and unpackaged chips.

[0046] The support, that is to say the process backup, relates in particular to the following areas:

- CIM,
- process monitoring,
- a transportation system for delivering the finished semiconductor chips,
- coordination of production
- backup for the respective production sites.

[0047] Process technology and process integration relates in particular to

- the process integration of logic chips,
- the process integration of memory chips,
- product engineering,
- the monitoring and improving of defect densities in manufacture,
- the monitoring of electrical parameters in the products manufactured,
- enhancement of the yield of the chips manufactured,
- a physical failure analysis.

[0048] **Figure 2** shows a semiconductor chip production installation, in other words a semiconductor chip factory 200, with a multiplicity of semiconductor chip production sub-installations 201, which are used for processing raw materials, for example a silicon wafer or a wafer made of other semiconductor materials (germanium, gallium-arsenide, indium-phosphide, etc.), in order to produce semiconductor chips from the raw materials.

[0049] A customary manufacturing process for manufacturing a semiconductor chip has hundreds of different process steps, in which lithographic steps, etching steps, CMP steps, steps for applying materials to the respective wafer to be processed, or else steps for doping or implanting doping atoms in the wafer to be processed are carried out in various sequences. In the case of all these process steps, values of process parameters which can be subjected to a later statistical analysis are recorded.

[0050] This results in the paths represented in figure 2 by lines 202, which represent the path of a wafer or lot of wafers through the semiconductor chip production installation 200. In the semiconductor chip production installation 200 there are a multiplicity of sensors, which are assigned to the respective sub-production installations 201 and an even greater amount of process data (raw data), which are respectively acquired by the sensors and processed as explained in more detail below, are recorded. A respective sensor may be integrated into a respective machine (integrated sensor) or be attached separately to a respective machine (external sensor).

[0051] Hereafter, the production sub-installations 201 are also referred to as machines 201.

[0052] **Figure 3** shows by way of example the data flow for process data, which are acquired on a machine 201 by means of an integrated sensor or by means of an external sensor 301. Each sensor 301, it being possible for any desired number of integrated and/or external sensors to be provided, acquires the parameters of the machine 201 which are respectively predetermined for it, for

example physical or chemical states in a process chamber, the position of a robot arm, etc. Examples of process parameters in the manufacture of a wafer are the misalignment, i.e. the positioning inaccuracy, within a positioning step, the temperature during a process step, the gas flow during a process step, the time duration of a process step or the pressure during a process step.

[0053] The sensor 301 is coupled via an SECS interface 302, which is set up for data communication according to the SECS standards, to a local communication network (**L**ocal **A**rea **N**etwork, LAN) 306.

[0054] According to the SECS standards, files are generated by the sensor 301 and the SECS interface 302 according to the PDSF format (**P**rocess **D**ata **S**tandard **F**ormat), also referred to hereafter as PDSF files 303 and also log files 304, the PDSF files 303 and the log files 304 being stored as data in a memory 307.

[0055] The PDSF files 303 contain, for example, analog data from different channels, that is to say from different internal (i.e. integrated) and/or external sensors 301, which may be attached to a machine 201. The process data generated are stored in the memory 307.

[0056] The memory 307 stores the process data in such a way that they can be assigned to the wafers after completion of the wafers and makes the process data available for later statistical analysis. The statistical analysis is carried out by means of an evaluation unit 308. The statistical analysis of the evaluation unit 308 serves the purpose of providing a selection criterion with the aid of which a random sample can be determined from wafers of a production lot, which random sample is subjected to a subsequent quality control measurement (SPC measurement).

[0057] Represented in **figure 4** is a distribution of the values of a process parameter which were recorded in the manufacturing process of a wafer. Chosen as an example was a process parameter which shows the misalignment, i.e. the deviation in the X and/or Y direction from a prescribed position of the wafer, which prescribed position it is intended to assume during processing. The process

data represented are on-line process data of a lot in lithography. The process data are acquired during the manufacturing process by an exposure machine and transmitted by means of a LAN network. The variation of the values of the process parameter which can be seen in figure 4 shows the natural process variation, i.e. the variation of the alignment quality of the wafers.

[0058] The value of the misalignment is determined as a process parameter for each wafer, as described above. It is consequently available without further time-consuming and costly measurement. The distribution of the values of the misalignment of all the wafers of a lot which is to be characterized by means of a quality monitoring test is created by means of a statistical analysis.

[0059] In the exemplary embodiment, the misalignment values (process parameters) of all the wafers are entered in a diagram in the statistical analysis. This produces a two-dimensional histogram in which the misalignment values of the wafers are plotted against the wafer numbers. Furthermore, the mean value or median of the process parameter of all the wafers of the lot is calculated by means of the statistical analysis and likewise entered in the two-dimensional distribution. On the basis of this two-dimensional distribution and the corresponding limit value, it can then be investigated by means of the analysis which wafers are particularly suitable for characterizing the lot.

[0060] In figure 4, the values for a lot comprising 50 wafers are entered. By means of the analysis, the wafers which best characterize the lot in this process parameter are then determined. On a random sample of the wafers which best characterize the lot, test measurements which characterize the quality of the wafer, and consequently the quality of the overall lot, are then subsequently carried out. In the exemplary embodiment, the mean value of all the misalignment values is entered as a horizontal line 409. In addition, the variation 410 of the distribution is entered. For the test measurement, a random sample, generally a single wafer, which lies in its alignment value close to the mean value of the distribution is selected. In figure 4, this is, for example, the wafer 411. With the selection of the

wafer 411 it is ensured that a typical representative of the lot is taken for characterizing the overall lot. As a further selection criterion in addition to the mean value depicted, the median of the distribution could also be used. The median has the advantage over the arithmetic mean value that the median is not influenced as strongly by wafers which have values for the process parameter used that deviate strongly from the mean value of the process data of the other wafers. That is to say that outliers of the values of the process parameter are not such a strong factor when calculating the median as when calculating the mean value. Consequently, when the median is used as a selection criterion for the selection of the random sample, an improved statement is obtained with respect to the quality of the wafers of a lot.

[0061] According to this exemplary embodiment, in addition to the average quality of the lot, the variation of the production qualities is also investigated. For this purpose, in addition to the random sample from the midst of the distribution, a random sample from the border of the distribution is also subjected to a test measurement. In figure 4, this would be, for example, the wafer 412, with the maximum distance of the process parameter from the mean value of the process parameter being assumed here as the variation. Alternatively, a 1σ range around the mean value of the distribution may also be assumed, for example, as the variation. In the distribution shown in figure 4, this would correspond, for example, to the wafer 413. Alternatively, the variation of the product qualities may also be determined directly from the variation of the distribution.

[0062] Representative statements concerning the overall lot can then be obtained by means of a quality investigation measurement of the two wafers 411 and 412. This applies both to the mean value of the distribution and to the variation of the distribution. Informative cp values or cpk values of the manufacturing process can be obtained. Consequently, an overall lot of wafers can be investigated with regard to its quality properties in a simple manner. The required number of time- and cost-intensive test measurements is minimized.

According to the invention, the variation can also be determined directly by means of the on-line process data.

[0063] If it is evident from the on-line data of the process parameters that no change has occurred in the manufacturing process in comparison with a test measurement which was carried out on wafers produced by means of the same manufacturing process, the number of wafers which are subjected to a test measurement can be reduced further.

[0064] To sum up, the invention provides a method and a device for the monitoring of the product quality of a physical object in a manufacturing process in which a random sample of physical objects is selected by means of recorded data of process parameters and a statistical analysis, which sample is used in a subsequent test measurement for determining the quality of the physical object. By means of this SPC measurement, the overall lot can subsequently be characterized. The method according to the invention has the advantage over the prior art that a substantiated statement concerning the production quality of an overall lot can be made with little expenditure on test measurements. Consequently, advantages of the method according to the invention are, for example, a reduction in the number of random sample measurements required, and consequently a reduction in the machine capacity requirement, an improvement in the process and product control and greater automation of the sample selection. The method according to the invention allows for the first time an active random sample selection on the basis of process data. By means of the method, the entirety of a lot is characterized, and not just one more or less representative random sample. If on-line measured values of a manufacturing process are evaluated for the monitoring of the manufacturing process, as is the case for example with APC (Advanced Process Control), it is possible to indicate which wafer characterizes the distribution of the on-line measured values particularly well.

~~The following documents are cited in this document:~~

~~[1] C.K. Lakshminarayan, "Overview of outlier methods in SC manufacturing", TI Technical Journal 1998~~

~~[2] US 5 422 724~~

~~[3] DE 198 47 631 A1~~